Water Resources

HIGHWOOD RIVER INSTREAM FLOW NEEDS STUDY

Alberta
ENVIRONMENT

HIGHWOOD RIVER INSTREAM FLOW NEEDS STUDY

Prepared by

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EXECUTIVE SUMMARY

An instream flow needs study of the lower Highwood River was initiated by the Planning Division of Alberta Environment in 1983. The objectives of the study were to define the inter-relationships between river flow and:

- physical habitat for sportfish
- temperature
- oxygen.

The study also considered the flows necessary to maintain the health and ecological diversity of the aquatic ecosystem and to provide for municipal waste assimilation below the Town of High River.

This report reviews the seasonal distribution and occurrence of sportfish species which use the lower Highwood River and describes the methods used to determine the physical fish habitat and water quality conditions necessary for certain levels of protection. Monitoring of river oxygen, temperature and habitat conditions was conducted during 1983, 1984 and 1985, with emphasis placed on the low flow periods. The results of this work are integrated into the report.

Predictive models for fish habitat, temperature and oxygen were developed during the course of this work. Using these models, quantitative assessments of the implications of any future instream flow regimes proposed for the lower Highwood River can be made.

Four levels of habitat protection were considered in determining the physical habitat requirements for rainbow trout and mountain whitefish in the Highwood River reach from Highway 2 bridge to Sheep River confluence. The flows necessary to provide 70, 75, 80 and 85 percent levels of median physical habitat were calculated for the mid-April to mid-October period. Flows for a 70 percent level of habitat protection ranged from 88 cfs in late September to 297 cfs in the first week of July, whereas for an 85 percent level of protection, flows ranged from 138 cfs to 466 cfs at corresponding times. The flows could be met by natural flows a minimum of 68 percent of the time to a maximum of 100 percent of the time. Under natural flow conditions, flows corresponding to the 70, 75, 80 and 85 percent levels of habitat protection were available an average of 97.2, 94.7, 90.4 and 85.2 percent of the time, respectively. In all cases, mid-May to June protection flows were met 100 percent of the time. The removal of peak runoff flows in these months would probably improve habitat conditions for fish.

Between July 1 and August 15 in some years, the lower Highwood River has experienced occasional fish kills of varying degrees of severity. Typically, mountain whitefish is the sportfish species most frequently involved. Fish kill events coincide with periods of low flow and high ambient air temperature over several consecutive days and nights. Monitoring results demonstrate that the danger of attaining hazardous conditions arises when water temperatures reach 24°C and oxygen levels drop below 4 mg/L. Under natural flow conditions in the lower Highwood River, the probability of attaining these temperature and oxygen levels are about 1.5 percent and 4 percent of the time, respectively.

In order to prevent the occurrence of hazardous conditions for sportfish during periods of high ambient air temperature between July 1 and August 15, a flow of 282 cfs is required for temperature protection and 212 cfs is required for oxygen protection.

Flows in the range required for sportfish physical habitat protection are sufficient to protect other components of the aquatic community as well. Adequate assimilation of municipal wastes will also be ensured at these flow levels.

The report is not intended to specify a minimum flow for the Highwood River. Further definition of the Little Bow storage project and the results of discussions with special interest groups and other government agencies will be required prior to the establishment of an instream flow regime.

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1.0 INTRODUCTION

The Highwood River supports a multitude of water uses, with the major consumptive use being irrigation in the Little Bow basin. Since the mid-1970's, irrigation licensing has increased dramatically from less than 2,000 acre-feet in 1975 to approximately 19,000 acre-feet in 1984. The major consumptive use of water along the Highwood River mainstem is also irrigation, with licenced volumes totalling about 4,000 acre-feet in 1985. Highwood River water supports other consumptive uses (e.g., domestic, industrial) and is used by the Town of High River for effluent assimilation.

The heaviest demand period for irrigation water supply is in July and August. Natural Highwood River flows are low in these months, whereas in May and June, when consumptive demands are low, flows are generally high. In dry years, Highwood River flows in the summer months have been insufficient to supply the demands in the Little Bow basin and to accommodate the various water uses in the Highwood River itself. In 1984 and 1985, for example, up to 60 per cent of the Highwood River flow in late July and early August was diverted to the Little Bow basin through the Little Bow and Squaw Coulee diversions. These heavy withdrawals have been implicated in exacerbating undesirable water quality and fish habitat conditions in the Highwood River below the diversions. Excessive weed growth, decreased assimilation capacity, reduction in physical habitat and lethal temperature and/or oxygen conditions for fish have been periodically experienced.

Alberta Environment initiated an instream flow study in the Lower Highwood River Basin in 1983 at the request of the then Director of Planning Division, Carl Primus. Work conducted under the study was divided into three broad categories:

1. review of historical information on the flows, water quality and biological resources of the lower Highwood River.

2. hydraulics and fisheries field studies and modelling to define the relationship between stream flows and fish habitat.

3. water quality monitoring and modelling to define the relationship between important water quality parameters (oxygen and temperature) and stream flows.

The study was intended to provide background information which could be used in the future in establishing instream or minimum flows for the Highwood River.

The study team members were drawn from Alberta Environment and Fish and Wildlife Division. Their role was to provide advice and resource expertise to the study managers in the Environmental Assessment Section, Planning Division. The study team was composed of the following individuals:

Bryan Kemper, Study Manager	Environmental Assessment Section
Ron Middleton	Environmental Assessment Section
Brenda Brassard	Environmental Assessment Section
Jack Glenn	Bow River Basin Planner
Alan Locke	Habitat Branch, Fish and Wildlife Division
Al Sosiak	Fisheries Branch, Fish and Wildlife Division
Shirley Charlton-Nicholson	Pollution Control Division
Ron Bothe	Technical Services Division

Field investigations spanned the period from 1983 to 1986 and included the low flow periods of 1983, 1984 and 1985. In response to the abnormally low flows in the Highwood River and the significant irrigation withdrawals which occurred during the summer of these years, the department initiated a water quality monitoring program to document flow, water temperature and oxygen conditions. The results of those studies have been integrated into this report.

1.1 OBJECTIVES

The objectives of this report are to describe the important instream uses of water in the lower Highwood River and where possible, to define the interrelationship between each of these uses and change in water quantity and quality.

A review of current instream water uses established the following objectives:

1. prevent significant fish kills due to temperature and/or oxygen stress in the July-August period.
2. maintain suitable physical habitat conditions for the sportfish populations present.

Further to these objectives, the study considered the flows necessary to provide for municipal waste assimilation and to maintain the health and diversity of aquatic populations.

Finally, the report provides flows which, during the open-water period, would meet the above objectives for the lower Highwood River in the reach between Aldersyde and the mouth of the Sheep River.

2.0 FISHERIES USE OF THE HIGHWOOD RIVER

Determination of instream flow needs for the Highwood River is particularly important since the river supports large and valuable sportfish populations. Mountain whitefish and rainbow trout are the major resident sportfish species. The upper Highwood and Sheep River systems provide an estimated 90 per cent of spawning and rearing areas for the Bow River rainbow trout population. The study area is therefore an important migration corridor for this population. The continued growth and success of the world class Bow River trout fishery is dependent upon the maintenance of access and suitable spawning and rearing habitat in the Highwood River and its tributaries.

A summary of distribution, life history and movements of rainbow trout and mountain whitefish is provided below. Further biological and environmental information pertaining to Highwood River fisheries is contained in a report by Planning Services Branch, May, 1986, titled "A Summary of Biological and Environmental Information Pertaining to Fisheries in the Highwood River System."

2.1 RAINBOW TROUT

Rainbow trout are spring spawners and are known to move up the Highwood and Sheep rivers from the Bow River in late April and early May. Spawning occurs in May in the upper tributaries and mainstem of both the Highwood and Sheep Rivers. Eggs incubate in river gravels, with fry emerging throughout July and early August. Some fry remain in the nursery streams while others drift downstream, seeking suitable rearing habitat. Young-of-year, juvenile and a few adults are found in suitable habitat throughout the Highwood River in the open water months. The

extent of overwintering by trout in the mainstem of the Highwood River is unknown, though young-of-year and juveniles reside in the upper Highwood and its tributaries and are known to successfully overwinter there. Most appear to migrate downstream during their second year.

2.2 MOUNTAIN WHITEFISH

Mountain whitefish spawn in late September and October in shallow riffle areas adjacent to deep pools in the mainstem of the Highwood and Sheep rivers. From late July, until the spawning period, adults become more concentrated in these pools, often accompanied by juveniles. Following spawning, whitefish move downstream and overwinter in the lower Highwood system and the Bow River. In spring, they appear to move upstream and distribute themselves in areas providing suitable habitat to feed over the summer. Eggs incubate in the Highwood and Sheep River gravels until April, when the fry emerge and distribute themselves in areas of suitable habitat throughout the system. In the open water period, all life stages are common throughout the river, except in a weedy, slow-moving reach between High River and Aldersyde where little salmonid habitat has been found.

A summary of life history events for both mountain whitefish and rainbow trout is provided in Table 1.

2.3 SEASONAL OCCURRENCE AND DISTRIBUTION OF SPORTFISH

Various life stages of rainbow trout and mountain whitefish are present in the lower Highwood River throughout the year. Mountain whitefish are the most abundant sportfish species, with young-of-year present from April onwards, and juveniles and adults residing, moving and feeding throughout the Highwood system on a year-round basis. The

Table 1

SUMMARY OF RAINBOW TROUT AND MOUNTAIN WHITEFISH
LIFE HISTORY EVENTS IN HIGHWOOD SYSTEM

SPECIES	LIFE STAGE	UTILIZATION	MONTH J F M A M J J A S O N D
Rainbow Trout	Adults	Feeding	? ********** ?
		Overwintering	******* ******
		Upstream Migration	***
		Spawning	****
		Post-spawning Downstream Migration	******
	Eggs	Incubation	******
	Fry	Emergence	****
	Y-O-Y & Juvenile	Rearing	**********
	Y-O-Y	Downstream Dispersal	***
	Juvenile	Downstream Movement	*****
Mountain Whitefish	Adults	Feeding and Overwintering	**********
		Pre-spawning Schooling	******
		Spawning	***
		Downstream Migration	****
	Eggs	Incubation	********** ******
	Fry	Emergence	****
	Y-O-Y & Juvenile	Rearing and Overwintering	**********

Highwood River has a resident rainbow trout population and is also used extensively by Bow River rainbow trout. Spawning migrations occur through the lower Highwood corridor starting in April, with most downstream adult migration complete by July though the timing of downstream migration may vary from year to year. Rearing of young-of-year and juveniles occurs in suitable habitat areas. Feeding by adult resident trout, and by Bow River rainbow trout (when suitable habitat conditions occur) takes place in the lower Highwood throughout the open water months.

All of the different life stages of mountain whitefish and rainbow trout have a range of preferred environmental conditions and are vulnerable when these conditions are not met. In the lower Highwood River, the months of July and August are sensitive times for sportfish. Discharges are naturally low in these months and diversions from the Highwood River to supply irrigation demands are at a maximum. Weed growth is abundant in the river between High River and Aldersyde, and this can result in large variations in oxygen concentrations between day and night. At low discharges, river water is subject to rapid solar heating, depending on weather conditions. At times in July and August, conditions in the lower Highwood River have deteriorated to the point where fish kills occur.

Fish kills have been experienced in the Highwood River in July and/or August of 1977, 1979, 1983, 1984 and 1985. In each of these five years, natural flows in the Highwood River were well below average, with diversions further reducing the flow. Above-average air temperatures on long hot, sunny days have also been associated with fish kills, as the

shallow water heats rapidly. Detailed information related to fish kills is contained in a report by Planning Services Branch titled "A Summary of Biological and Environmental Information Pertaining to Fisheries in the Highwood River System."

In order to provide physical habitat conditions to sustain the various life stages of sportfish present in the lower Highwood River, instream flow needs must be determined. Since July and August are particularly sensitive months in terms of low flows and poor water quality conditions, definition of flows to prevent or reduce the occurrence of lethal temperature and oxygen levels is also needed. The following section describes how these instream flow needs were derived.

3.0 DETERMINATION OF INSTREAM FLOW NEEDS

Alberta Environment, in cooperation with Fish and Wildlife Division of the Forestry, Lands and Wildlife Department, initiated an instream flow needs study of the lower Highwood River in summer of 1983. The field program was designed to collect detailed hydraulic information and habitat use data by mountain whitefish and rainbow trout. The study continued in 1984 to collect sportfish habitat data over the complete open water season. A concurrent water quality sampling program was initiated in 1983 and has continued through to the fall of 1986. Additional field work including time of travel studies, macrophyte biomass determination and reach characterization was undertaken in the summer of 1986.

This section describes the fisheries studies and how the data collected were used to generate flows to provide for four levels of physical habitat protection ranging from 70 percent to 85 percent of that available at the median natural flow at Aldersyde. The water quality studies and modelling exercises which were used to define flows for temperature and oxygen protection are also described.

3.1 PHYSICAL HABITAT EVALUATION

3.1.1 Background

Streamflow is a major environmental factor affecting fish habitat and, therefore, the survival and production of fish populations. Given the importance of the Highwood River system in supporting sportfish populations and in providing a major source of recruitment for the Bow River trout fishery, a program was designed to formulate flows which would protect fish habitat in the lower Highwood River during periods of drought or low natural runoff.

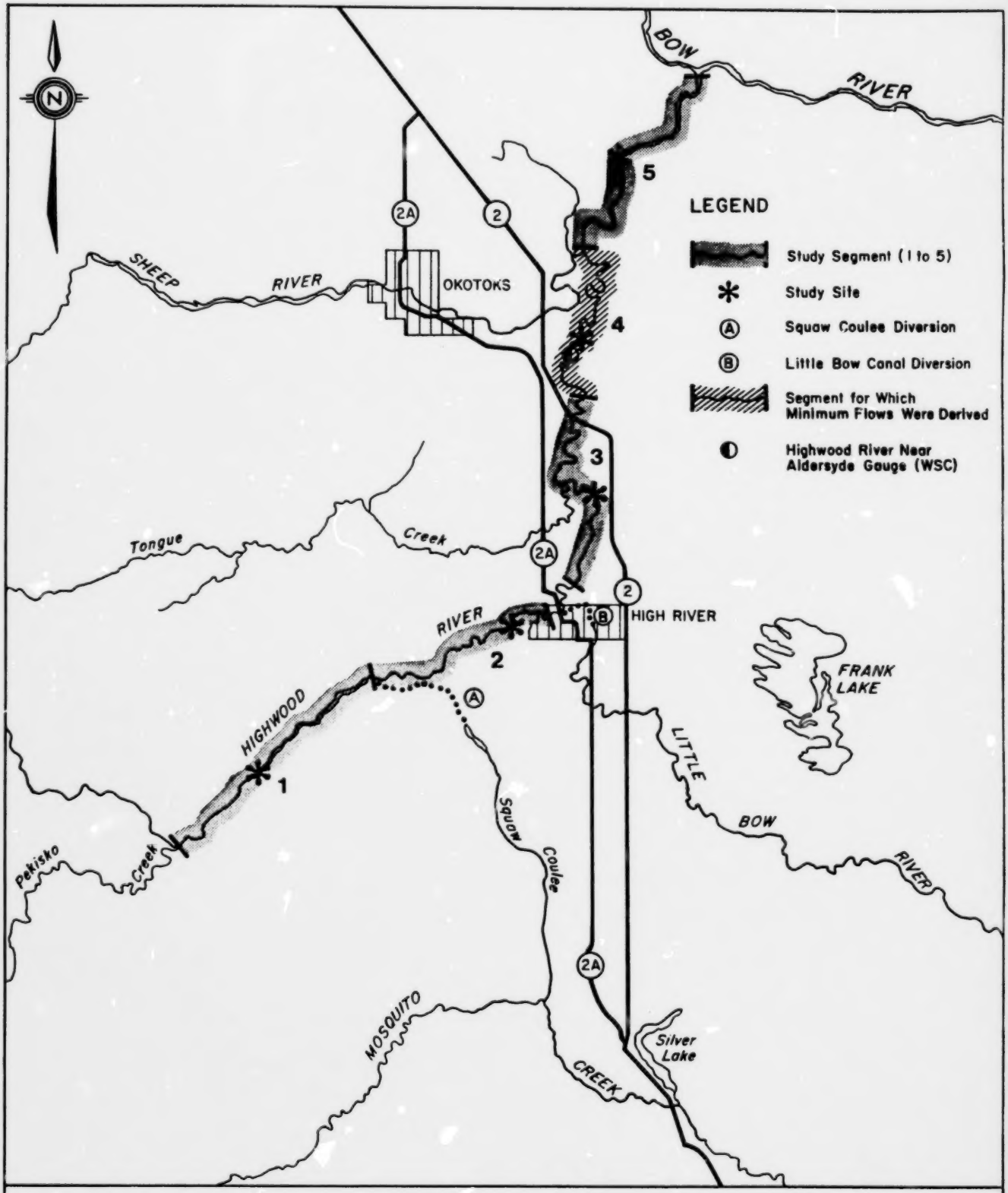
In order to derive physical habitat flows, it was first necessary to define the relationship between streamflow and fish habitat. Since it is not feasible to measure all flows and the attendant habitat under field conditions, computer models are used to simulate unmeasured flows and predict the amount of fish habitat available at these flows. The computer programs used for streamflow/habitat analysis in this study are part of the Physical Habitat Simulation System (PHABSIM), developed by the Instream Flow and Aquatic Systems Group of the United States Fish and Wildlife Service.

Mountain whitefish and rainbow trout are the predominant sportfish species in the Highwood River system. The life stages of these species (adult, juvenile, young-of-year and spawning or egg incubation) were the focus of the habitat/flow analyses.

The following section describes the methods used in collecting field observations, carrying out habitat-flow analyses and deriving physical habitat flows for Segment 4 of the Highwood River (Figure 1).

3.1.2 Study Sites

The study area encompasses those sections of the Highwood River most likely to be affected by diversions from the Highwood River to the Little Bow basin. It extends from the Pekisko Creek confluence down to the Highwood River mouth on the Bow River. This section was divided into five river segments (Figure 1), each being relatively homogenous with respect to channel characteristics and flow regime.



MAP OF THE STUDY AREA
SHOWING LOCATION OF SEGMENT BOUNDARIES
AND STUDY SITES ON THE HIGHWOOD RIVER

SCALE 1:250 000

FIGURE 1

A study site was established in each of these segments. Each study site was representative of the segment in terms of microhabitat features; namely, water depth and velocity, substrate and cover, as well as major habitat features such as islands or gravel bars.

Physical habitat flows have been computed to date only for Segment 4, which extends from about the Highway 2 crossing downstream to the Sheep River confluence. This segment contains significant populations of rainbow trout and mountain whitefish during various times of the year, and is subjected to major flow reductions during the summer period. Segment 3, which is located below the town of High River and immediately upstream of Segment 4, also experiences the same flow reductions, but has generally poorer physical habitat for salmonid fish populations. Juvenile mountain whitefish, however, are known to use this segment.

3.1.3 Collection of PHABSIM Field Data

Hydraulic and biological data needed for input in the PHABSIM models was collected by IEC Beak (1984, 1985) during field operations in late summer and fall of 1983, and spring and summer of 1984 at each of the five study sites.

3.1.3.1 Hydraulic Observations

Three sets of hydraulic measurements, representing low, medium and high flows, were collected at each site. Measurements were made at each site along a series of cross-sections or transects of channel bed configurations, water surface elevations (stage), velocities and depths. Substrate and cover along each transect were assessed and quantified.

3.1.3.2 Biological Observations

Information on habitat utilization by the different life stages of rainbow trout and mountain whitefish were collected at the five study sites. Methods of direct observation included diving, electrofishing, and observations from the riverbank. Observations of spawning activity were complemented with sampling for eggs.

Observations during the summer and early fall period were conducted by an underwater observer. Each study site was sampled systematically so that the amount of effort per habitat type (riffle, run or pool) was proportional to its abundance within the site.

Whenever a sportfish was observed, a numbered marker was set down to indicate its exact location. Only the locations of undisturbed fish engaged in a feeding or holding activity were marked. Marker number, species, and life stage were recorded. Following the movement of the diver through an area, measurements of microhabitat parameters (depth, velocity, substrate and cover) were made at each marker.

Rainbow trout juveniles were found to occur mainly under cover during cold temperatures (7°C or less) during the early spring period. Electrofishing was employed, therefore, as a means of documenting habitat utilization of sportfish holding under cover during the cold-water period. The sampling protocol at each study site was similar to that of underwater

observation, except that a three-man crew equipped with a backpack electrofish was used for sampling rather than a diver. Whenever a sportfish was drawn from cover and captured, a marker was set down to indicate the estimated location of the fish prior to being shocked. Following movement of the crew through the site, measurements of microhabitat parameters were made at each marker.

The microhabitat requirements of spring-spawning rainbow trout were estimated by measuring the conditions present during the incubation period shortly following spawning. Measurements were collected at active redds which were defined as any distinct gravel depressions known to be recently made and containing viable eggs, or occupied by a single or pair of adult rainbow trout. Because of the small sample size of active redds at the study sites, observations were also made in other areas identified by Alberta Fish and Wildlife Division as having deposits of clean gravel suitable for spawning trout. Portions of the Highwood River were examined as far upstream as Trap Creek, about 20 km upstream of the Town of Longview.

Monitoring of spawning activity was accomplished by direct observation from the riverbank, and by the careful sampling of eggs at suspected redds. Where active redds were identified, a numbered marker was set down and measurements made of depth, velocity and substrate immediately upstream of the gravel depression.

Mountain whitefish do not spawn in redds as do rainbow trout, but rather are "broadcast" spawners. Their eggs are often found, therefore, at variable distances downstream from where spawning occurs. Since mountain whitefish spawn at night, direct observation is extremely difficult (IEC Beak: 1984), it was necessary to make observations on egg distribution and incubation rather than spawning.

A modified Neil Hess benthic sampler was used to sample for eggs at ten-metre intervals along two study sites in Segments 2 and 5, respectively. The substrate inside the sampler was roiled and eggs and other fine debris were washed by the current into a funnel net and plastic sample jar. The number of live eggs were then counted by hand. A marker was used to indicate each location where viable eggs were found. Following the completion of egg sampling at a given study site, measurements of microhabitat parameters (depth, velocity and substrate) were made at marker locations.

3.1.4 Computer Simulation of Fish Habitat and Flows (PHABSIM)

The PHABSIM system was used to analyze the relationship between streamflow and fish habitat in this study. PHABSIM is a collection of computer programs developed for this purpose. PHABSIM includes the following three components. The Water Surface Profile (WSP) and IFG_4 hydraulic simulation programs were used in combination in order to predict depth, velocity, and discharge at study sites for simulated flows. FISHFIL is a biological data file that contains the habitat preference curves for target species and life stages.

These curves relate fish occurrence to the microhabitat variables of depth, velocity, substrate, and cover. HABTAT is a program that combines the hydraulic and biological information from the above two components to predict weighted usable area (WUA) for a particular site and flow. WUA represents the portion of the study site that is suitable habitat for a particular species/life stage. The PHABSIM model assumes that water quality conditions are constant over the range of flows modelled; therefore, physical habitat flows must be revised when restrictive water quality conditions are encountered.

3.1.4.1 Hydraulic Models

The Hydrology Branch, Technical Services Division, of Alberta Environment calibrated the hydraulic models, which is a pre-requisite to carrying out production runs of flow simulations. The WSP hydraulic model was used to derive a stage-discharge relationship, or rating curve, for each cross-section of each study site. These calibrated rating curves were then entered directly into the IFG_4 hydraulic model. Three separate IFG_4 data sets were prepared, one each for the low, medium and high discharge ranges of the rating curves.

3.1.4.2 Habitat Preference Curves

Habitat preference curves are required as input into the PHABSIM system for analysis of the relationship between river discharge and fish habitat. These curves define what values of the different microhabitat parameters (i.e., depth,

velocity, substrate and cover) are suitable for a particular species/life stage. Habitat preference curves reflect the "preference" of a particular species/life stage for a given set of microhabitat conditions, since they are weighted to take into account the range of microhabitat conditions that were available during the period of fish observations. For example, a particular type of habitat that has a low occurrence in the study area will have a higher set of preference values than a more abundant type of habitat if use of the two habitat types by a particular species/life stage is equal.

The approach taken in developing preference curves was to overlay habitat utilization and availability data to produce habitat preference values. Habitat availability was computed by using the IFG_4 hydraulic model to simulate flows and microhabitat conditions present during the different dates of fish observations. The preference values were plotted against each microhabitat parameter (i.e., depth, velocity, substrate and cover) for each target species and life stage. A habitat preference curve was then fitted through these points. These are composite curves in that they include fisheries data from each of the five study sites where a particular species/life stage occurred (Table 2).

Refinement of habitat preference curves was accomplished through consultation among biologists from Alberta Environment and Alberta Fish and Wildlife Division who have observed the target species over a broad range of environmental conditions.

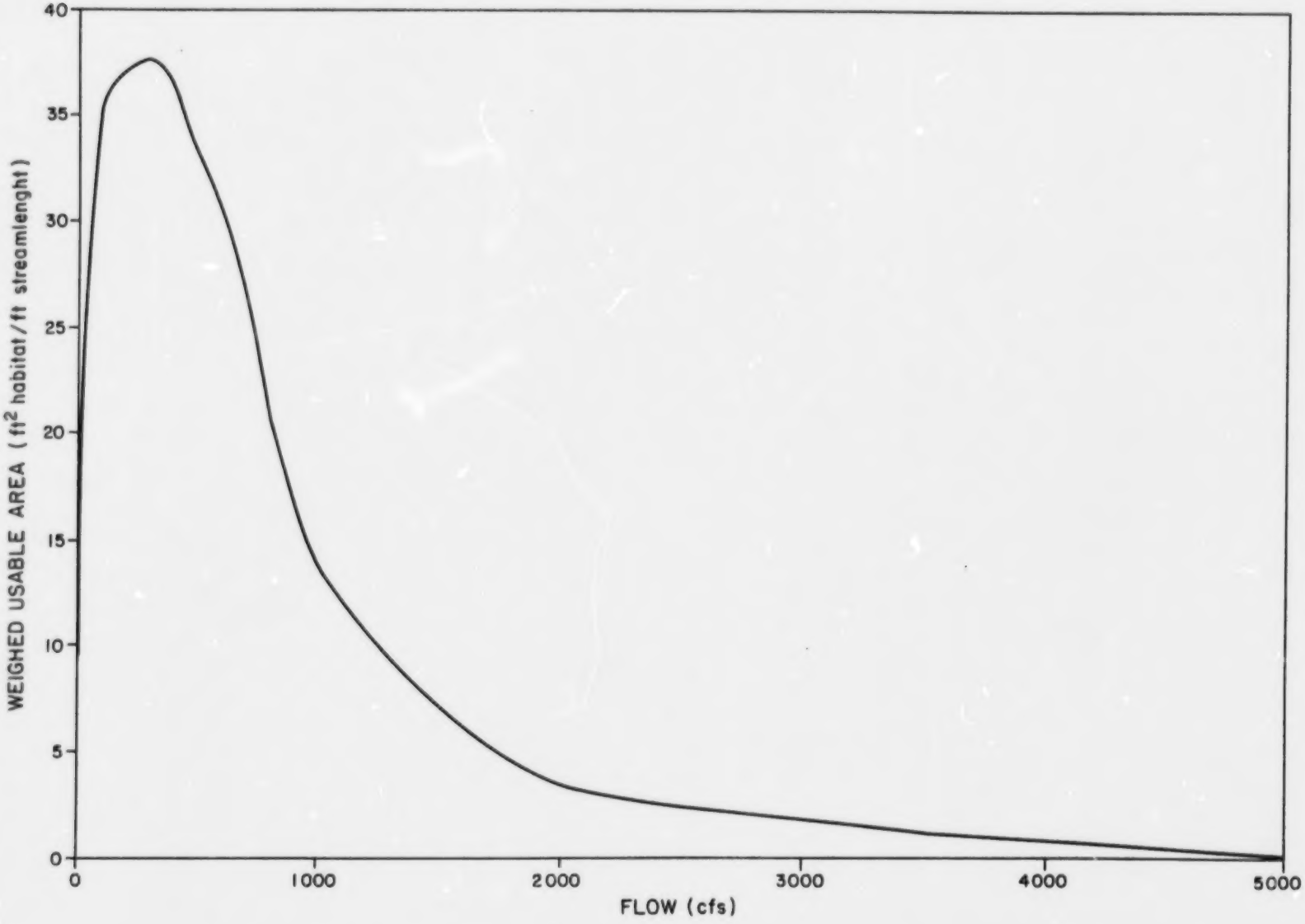
TABLE 2
HIGHWOOD RIVER STUDY SITES WHERE HABITAT UTILIZATION DATA WERE COLLECTED DURING THE 1983 AND 1984 FIELD PROGRAM

SPECIES	STUDY SITES OCCUPIED
Mountain Whitefish	
Adults	1, 2, 5
Juveniles	1, 2, 4, 5
Young-of-Year	1, 2, 4, 5
Egg Incubation	2, 5
Rainbow Trout	
Juveniles	1, 2, 4, 5
Young-of-Year	1, 2, 5
Spawning[a]	1

a - Habitat utilization data also collected upstream of study area boundary.

3.1.4.3 Habitat/Flow Analyses

The HABITAT computer model was used to simulate the amount of suitable habitat (i.e., WUA) available over a range of flows for each target species/life stage at the study site corresponding to Segment 4. The range of flows simulated with the IFG_4 model were from 10 to 5,000 cfs (Figure 2). The results of these simulations were entered into the HABTAT model along with the FISHFIL data file which contained the habitat preference curves. Since three sets of IFG_4 model



HIGHWOOD RIVER SEGMENT 4

WEIGHTED USABLE AREA (WUA) VS. FLOW
RELATIONSHIP FOR RAINBOW TROUT YOUNG-OF-YEAR

FIGURE 2

runs were needed to simulate the entire range of flows, three sets of HABTAT model runs were also performed. The resultant habitat-flow relationship was derived by combining the three WUA vs. discharge curve segments for each species/life stage.

3.1.5 Computation of Physical Habitat Flows

The basic approach to organizing and analyzing information to derive physical habitat flows followed the method proposed by Geer (Geer, 1987) which takes into account fisheries management objectives, the natural streamflow regime, and the habitat versus flow relationship for a given study reach.

The study to date has focussed on Segment 4 of the Highwood River. Fisheries management objectives were obtained from Fish and Wildlife Division, and called for the provision of flows to protect both rainbow trout and mountain whitefish populations in the lower Highwood River, but with rainbow trout weighted over mountain whitefish by a ratio of 3:1. This ratio reflects the importance placed on the trout spawning and rearing habitat in the Highwood River system and is not a reflection of population size of these two species. The historical natural flow data used for analysis was generated by Hydrology Branch. The PHABSIM computer programs were employed to simulate the amount of suitable habitat (WUA) available over a range of flows for each species and life stage.

Biologically significant periods (BSP) were defined to describe the periods of time during the year in which the various life stages of trout or whitefish resided in Segment 4 (Table 3). Following

TABLE 3

BIOLOGICALLY SIGNIFICANT PERIODS (BSP) AND WEEKLY PRESENCE (X)
OF TARGET SPECIES AND LIFE STAGES IN HIGHWOOD RIVER
SEGMENT 4

	RAINBOW TROUT[1]				MOUNTAIN WHITEFISH[2]				
Month (wk)	S	Y	J	CJ	I	Y	J	A	
Nov (44-48)				X	X		X	X	BSP-1
Dec (49-52)				X	X		X	X	
Jan (1-4)				X	X		X	X	
Feb (5-8)				X	X		X	X	
Mar (9-13)				X	X		X	X	
Apr (14-17)				X	X	X	X	X	BSP-2
May (18-21)	X			X	X	X	X	X	BSP-3
Jun (22-26)	X	X	X			X	X	X	BSP-4
Jul (27-30)		X	X			X	X	X	BSP-5
Aug (31-35)		X	X			X	X	X	
Sep (36-39)		X	X			X	X	X	
Oct (40-43)		X	X		X	X	X	X	BSP-6

[1] Rainbow Trout

S = spawning
Y = young-of-year
J = juvenile
CJ = cold-water juvenile

[2] Mountain Whitefish

I = incubation
Y = young-of-year
J = juvenile
A = adult

discussions with personnel from Fish and Wildlife Division, adult rainbow trout were excluded from the analysis since the habitat preference curves generated for juvenile rainbow trout would also pertain to the stream-resident adult trout occurring in the lower Highwood River. Adult rainbow trout of Bow River origin are believed to comprise only a minor proportion of the trout population in Segment 4.

Composite habitat values were determined for each biologically significant period by means of relative weighting equations (Table 4). The composite habitat values are determined from the mean per cent deviations (MPD) and are a composite description of the deviations from optimal habitat by each species/life stage at a given flow and within a particular BSP. Included in these equations is the 3:1 weighting factor of rainbow trout over mountain whitefish. Within each BSP the best streamflow from the range of flows simulated would be the flow giving the lowest MPD value.

3.1.6 Physical Habitat Flow Criteria

The physical habitat flows for four levels of habitat protection were formulated on a weekly basis for each biologically significant period. They were defined as those flows providing protection to 70, 75, 80 and 85 percent of the habitat occurring at median historical natural flows or at optimum flows, whichever was less. Weeks 18 through 27 were the only weeks in which optimum flows were less than median natural flows. Natural flow frequency statistics were then examined to determine the frequency that each physical habitat flow was met or exceeded by natural flows over the period of record.

TABLE 4
COMPOSITE HABITAT EQUATIONS (MEAN PERCENT DEVIATIONS[MPD])
FOR BIOLOGICALLY SIGNIFICANT PERIODS (BSP)
AT HIGHWOOD RIVER SEGMENT 4.
TERMS IN EQUATIONS ARE INDIVIDUAL PERCENT DEVIATIONS (IPD)[1]

BSP1 - Nov, Dec, Jan, Feb, Mar

$$MPD = \frac{3(RBTR\ CJ) + (MTWT\ I + J + A)}{6}$$

BSP2 - Apr

$$MPD = \frac{3(RBTR\ CJ) + (MTWT\ I + Y + J + A)}{7}$$

BSP3 - May

$$MPD = \frac{3(RBTR\ S + CJ) + (MTWT\ I + Y + J + A)}{10}$$

BSP4 - June

$$MPD = \frac{3(RBTR\ S + Y + J) + (MTWT\ Y + J + A)}{12}$$

BSP5 - Jul, Aug, Sep

$$MPD = \frac{3(RBTR\ Y + J) + (MTWT\ F + J + A)}{9}$$

BSP6 - Oct

$$MPD = \frac{3(RBTR\ Y + J) + (MTWT\ I + Y + J + A)}{10}$$

[1] Definition of IPD Terms:

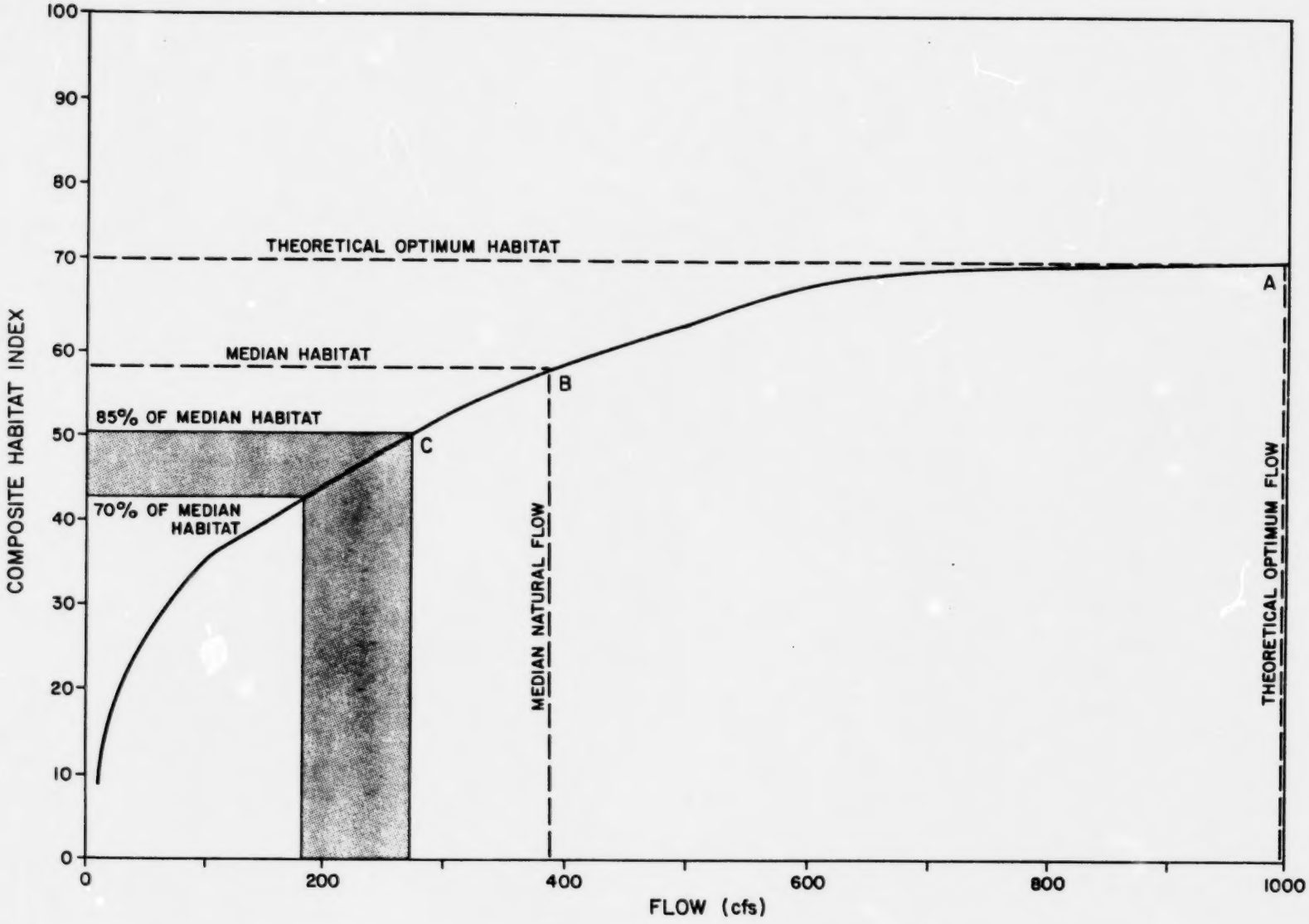
Rainbow Trout (RBTR)	Mountain Whitefish (MTWT)
S = spawning	I = incubation
Y = young-of-year	Y = young-of-year
J = juvenile	J = juvenile
CJ = cold-water juvenile	A = adult

Table 5 provides weekly physical habitat flows and natural flow exceedances for Segment 4 during the April 16 to October 14 period which includes the biologically critical summer low flow period. For all four levels of median habitat protection there are times when the minimum flows cannot be met under natural conditions, with the 85 percent level of protection met the least often. On average, however, the flows corresponding to 70, 75, 80 and 85 percent levels of habitat protection are available 97, 95, 90 and 85 percent of the time, respectively. It is noteworthy that the physical habitat flows in weeks 20 through 26 (mid-May and all of June) are exceeded at all times by the natural flows. In the other months, the physical habitat flows are met between 68 percent of the time (week 35 at 85 percent habitat protection level) and 99 percent of the time (week 37 at 70 percent habitat protection level). It is noteworthy that the physical habitat flows in weeks 20 through 26 (mid-May through June) are exceeded at all times by the natural flows.

Figure 3 illustrates an example (week 31) of composite habitat index values (determined from MPD values) corresponding to theoretical optimum, median natural, and physical habitat flows during the summer low flow period. The physical habitat flow corresponds to the composite habitat value representing 75 to 80 percent of the composite habitat occurring at the median natural flow. It is evident that the flow corresponding to the optimal composite habitat value is much greater than the median natural flow.

TABLE 5
PHYSICAL HABITAT FLOWS, NATURAL FLOW EXCEEDANCES AND
HABITAT PROTECTION LEVELS
HIGHWOOD RIVER SEGMENT 4

MONTH	JULIAN WEEK	HABITAT PROTECTION LEVEL:	70 PERCENT		75 PERCENT		80 PERCENT		85 PERCENT	
			Min. Flow (cfs)	Natural Flow Exceed. (%)	Min. Flow (cfs)	Natural Flow Exceed. (%)	Min. Flow (cfs)	Natural Flow Exceed. (%)	Min. Flow (cfs)	Natural Flow Exceed. (%)
April	16		134.2	89	162.4	82	190.7	74	211.9	72
	17		134.2	92	169.5	86	197.8	81	215.4	79
May	18		130.7	100	141.3	100	155.4	97	204.8	94
	19		130.7	100	141.3	100	155.4	100	204.8	98
	20		130.7	100	141.3	100	155.4	100	204.8	100
	21		130.7	100	141.3	100	155.4	100	204.8	100
June	22		144.8	100	173.0	100	211.9	100	247.2	100
	23		144.8	100	173.0	100	211.9	100	247.2	100
	24		144.8	100	173.0	100	211.9	100	247.2	100
	25		144.8	100	173.0	100	211.9	100	247.2	100
	26		144.8	100	173.0	100	211.9	100	247.2	100
July	27		296.6	98	346.1	98	395.5	94	466.2	88
	28		289.6	96	335.5	92	388.5	87	452.0	81
	29		264.9	94	303.7	92	349.6	81	384.9	80
	30		229.5	92	261.3	88	296.6	82	339.0	79
Aug.	31		190.7	94	218.9	90	247.2	86	275.5	79
	32		173.0	95	201.3	90	229.5	81	254.3	71
	33		144.8	96	173.0	91	197.8	79	222.5	71
	34		134.2	96	158.9	87	183.6	77	208.4	71
	35		120.1	97	141.3	90	162.4	81	190.7	68
Sept.	36		102.4	98	127.1	93	148.3	86	173.0	77
	37		91.8	99	105.9	98	130.7	94	151.9	84
	38		88.3	98	98.9	98	116.5	97	137.7	87
	39		88.3	98	98.9	98	116.5	97	137.7	88
Oct.	40		95.3	98	109.5	95	130.7	87	148.3	70
	41		91.8	97	102.4	94	120.1	89	141.3	79



HIGHWOOD RIVER SEGMENT 4

COMPOSITE HABITAT VALUES AND CORRESPONDING FLOWS FOR WEEK 31 OF BSP 5

FIGURE 3

3.2 WATER QUALITY EVALUATION

3.2.1 Background

A water quality monitoring program for the Highwood River was initiated in 1983 and continued through 1986. In addition to chemical analysis of water samples, macrophyte biomass determination was undertaken in the July--August period of each year. Details of these studies are contained in a report by Water Quality Control Branch titled "Ecological Characteristics of the Highwood River" (Charlton and Brennan, 1986).

The lower Highwood River receives sewage effluent from the Town of High River at the rate of about 1 cfs. In late July 1984, when the Highwood River flow below High River was about 90 cfs, the sewage lagoons became anoxic and their effluent discharge significantly added to the biochemical oxygen demand of the river. Nutrients from the sewage effluent have contributed to the extensive development of aquatic macrophytes in the reach below High River (Segment 3). Under conditions of low flow, respiration by aquatic macrophytes and other inchannel processes deplete the water column of oxygen in the late evening/early morning period, thereby contributing to fish kills.

Further, reduced streamflows permit rapid solar heating of water during periods of high ambient air temperature. When water temperature reaches 24°C, fish are subjected to thermal stress. Thermal stress and oxygen stress, either singly or in combination, can result in fish kills.

The water quality monitoring program and the review of historical information suggest that temperature and oxygen conditions limiting to fish have occurred only between July 1 and August 15. The water quality modelling effort was restricted to this period.

The modelling program, which was initiated in 1984, used the model "Water Quality for River and Reservoir Systems" (WQRRS) to aid in predicting the relationship between flow, temperature and oxygen. Initial calibration and verification of the model for July and August of 1984 and 1985 is described in HydroQual Consultants Inc. (1986a). Extensive field work was undertaken in 1986 to provide additional information needed to improve the accuracy of WQRRS simulations. In the fall of 1986, these data were used in re-calibrating and refining the model. Following re-calibration, the model was used to define minimum instream flow requirements to maintain adequate temperature and oxygen conditions in the lower Highwood River.

3.2.2 Water Quality Minimum Flow Criteria

Minimum oxygen and maximum temperature criteria were established for the reaches downstream of High River based upon the known use of the river by fish and the habitat characteristics of the river.

In Segment 3 (High River to downstream of Highway No. 2 Bridge) physical habitat conditions are limited by the low gradient, silt deposits and low velocities. This reach is essentially a travel

corridor for adult rainbow trout moving to and from upstream spawning areas and juvenile trout moving downstream to the Bow River. The mountain whitefish which are resident and highly migratory in the Highwood River also move through this reach. To maintain suitable water quality in Segment 3, the maximum temperature criterion was established at less than 24°C and the minimum oxygen criterion was established at 4 mg/L. The Alberta Surface Water Quality Objective is a minimum of 5 mg/L of oxygen.

In Segment 4 (downstream of Highway No. 2 Bridge to Sheep River confluence), the minimum oxygen criterion was set at 5 mg/L and the maximum temperature criterion was set at 24°C. These criteria recognize the resident adult and juvenile sportfish populations which inhabit Segment 4.

3.2.3 Field Studies and Model Calibration

In support of the modelling exercise, the following field studies were undertaken in the summer and fall of 1986:

- a survey of the Highwood River from High River to the mouth to determine dominant substrate type, channel width, depth and morphometry.
- delineation of zones of aquatic plant growth, relative coverage by component species and biomass estimates.
- dye studies to determine time-of-travel for the Highwood River from High River to the mouth under two conditions of low flow.
- determination of dissolved oxygen concentrations at paired sites located one to three hour's travel time apart, continuously for 24-48 hour periods. These studies were repeated for a variety of flows and at locations where macrophyte growth or river re-aeration are important.

- continuous monitoring of stream temperature at six sites - two above High River, three downstream of High River and one near the mouth of the Sheep River.
- routine water quality sampling fortnightly.
- selection and surveying of river cross sections between High River and the mouth, and establishment of a river profile.

Detailed information on these studies is presented in HydroQual Consultants Inc. (1986b) and in Charlton and Brennan (1986). A description of how the field results were used in re-calibrating the WQRRS model and subsequent application of the model is contained in HydroQual Consultants Inc. (1987). A general summary of model calibration and application is provided in this report.

The WQRRS model contains a hydraulics module and a water quality module. Each module is calibrated separately with the hydraulics module done first, since output from it is required as input to the water quality module.

Information on cross-sectional geometry and bottom elevation relative to a common datum, energy slope between cross-sections, distance between cross sections at left and right banks and thalweg, and bed roughness (Manning's n) is required by the hydraulics module. The objective of the hydraulic calibration procedure is to match the model stage-discharge relationships at various river cross-sections with those measured in the field. The results of the hydraulics model calibration include stage-discharge curves for each model reach, values of roughness and bed slopes for each reach and flow-elevation tables for input to the water quality module.

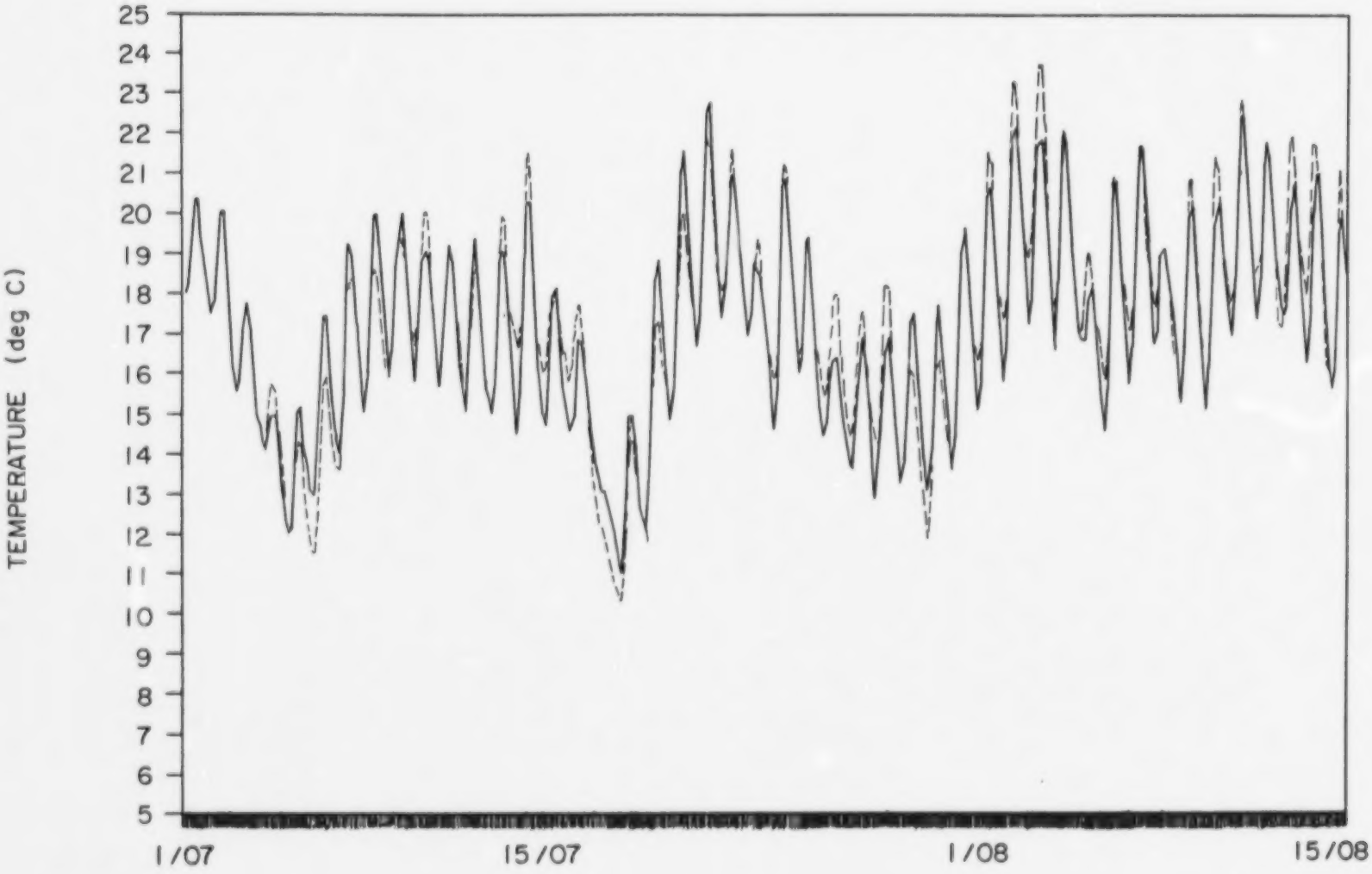
Additional data input to the water quality module includes headwater temperature (one hour interval), meteorological data (three-hour interval), organic sediment concentration, aquatic plant biomass and the water chemistry parameters of BOD, ammonia, nitrite, nitrate, ortho-phosphate and dissolved oxygen. The water quality calibration process is sequential, with temperature calibrated first followed by dissolved oxygen. WQRRS rate coefficients are set within reasonable physical, chemical and biological limits and are adjusted to compensate for known limnological conditions in the Highwood River.

3.2.3.1 Temperature Calibration

Calibration of the 1986 temperature model was undertaken for the period of July 1 to August 15 at three sites where thermograph data were available, namely upstream of Highway 2 crossing, upstream of the Sheep River confluence and approximately halfway between the Sheep River confluence and the Highwood River mouth. The average absolute difference between observed and predicted temperatures at these three locations was 0.78°C, 0.77°C and 0.70°C, respectively. The simulated versus observed plot for the site upstream of the Sheep River confluence is presented in Figure 4.

3.2.3.2 Oxygen Calibration

The oxygen calibration of WQRRS was undertaken for the period from July 21 to July 25, 1986. The calibration plot



TEMPERATURE CALIBRATION FOR HIGHWOOD RIVER UPSTREAM OF SHEEP RIVER CONFLUENCE, JULY 1 TO AUGUST 15, 1986

FIGURE 4

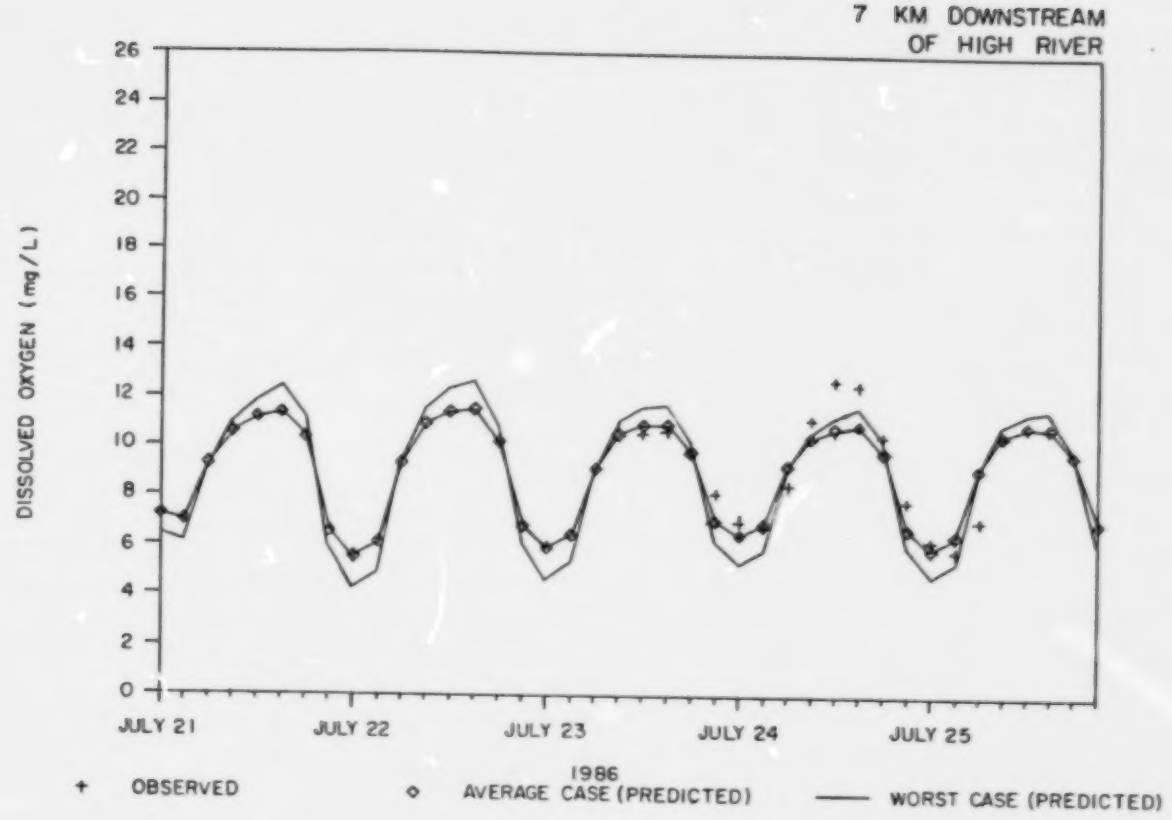
of predicted versus observed oxygen concentrations (Figure 5) shows good agreement on daily minimum oxygen.

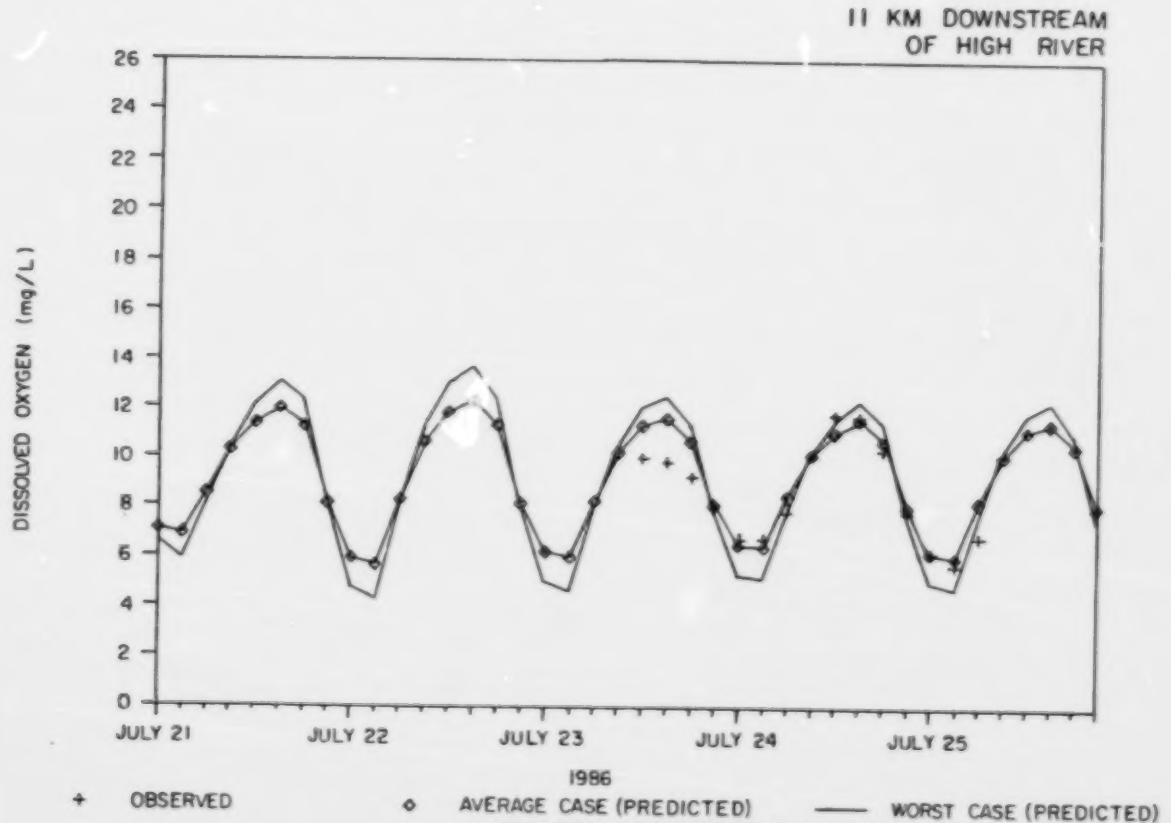
3.2.4 Derivation of Instream Flow Needs for Temperature and Oxygen Protection

3.2.4.1 Temperature

The Highwood River originates in the eastern slopes of the Rocky Mountains, descends rapidly through the foothills and meanders through the prairies to the Bow River. The river's velocity is reduced in the lower reaches, due mainly to topographic factors, and it becomes deeper and wider. The greater width exposes a greater surface area of water to atmospheric heating. Air temperature appears to be the primary factor controlling water temperature. Other factors, however, such as reduced velocity and shading also contribute to the effects of the naturally warmer air temperatures of the prairie region to produce higher water temperatures below High River. Substantially lower flows downstream of the Little Bow diversion and extensive macrophyte growth between High River and Aldersyde lead to further velocity reduction and increased heating, with this section of river experiencing the greatest water temperature increase per unit of length.

A review of conditions associated with fish kills in July and/or August of the 1977 to 1985 period revealed that high air temperatures and below-average streamflows were





OXYGEN CALIBRATION FOR HIGHWOOD RIVER AT
7 KM AND 11 KM DOWNSTREAM OF HIGH RIVER

FIGURE 5

experienced in all cases. Daily maximum air temperatures were in the high 20's or greater, and flows ranged from less than 100 cfs (3 cms) to more than 210 cfs (6 cms).

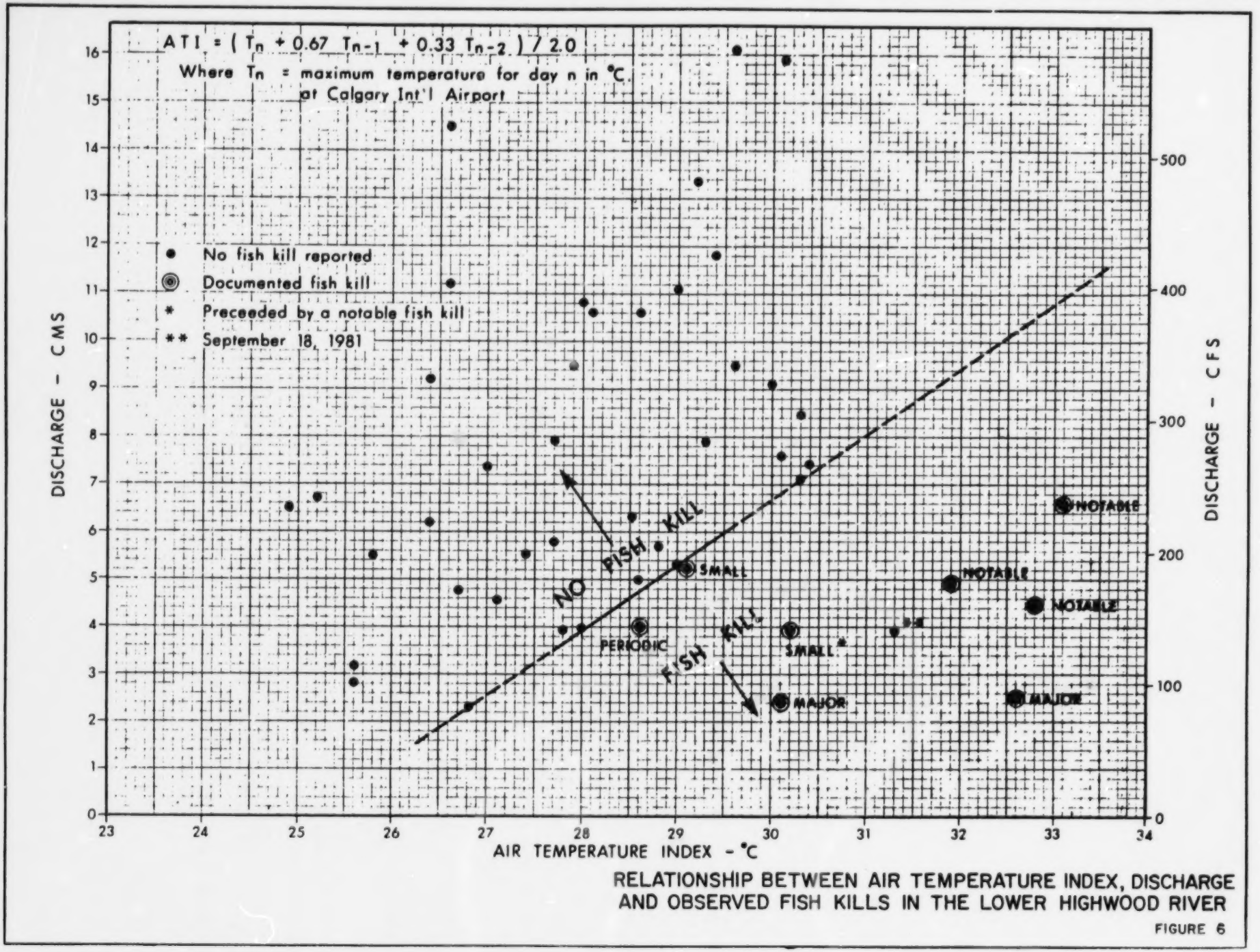
3.2.4.1.1 Preliminary Analysis of Temperature/Flow Relationship

Prior to the availability of the WQRRS model, an initial attempt to describe the relationship between air temperature, flows and fish kills, was undertaken by Hydrology Branch. An air temperature index was developed for all May through September data from 1977 to 1985, in the flow range of 0 cfs (0 cms) to 600 cfs (17 cms). Figure 6 provides the index and illustrates the results of the analysis. The index is based upon maximum daily air temperatures over three consecutive days. All fish kills have occurred when air temperatures have been high for at least three days while flows were less than 250 cfs (7 cms).

The flows necessary to move water temperatures out of the critical range cannot be determined from this analysis. The WQRRS computer model, which undertakes a detailed heat budget, is an appropriate tool to determine the relationship between streamflow and water temperature.

3.2.4.1.2 Application of WQRRS Temperature Model

The WQRRS temperature model was used to simulate water temperatures under natural flow conditions for July 19 to July 31,1984; July 1 to 12, 1985 and July 1 to



RELATIONSHIP BETWEEN AIR TEMPERATURE INDEX, DISCHARGE AND OBSERVED FISH KILLS IN THE LOWER HIGHWOOD RIVER

FIGURE 6

August 15, 1986. The 1984 and 1985 simulation periods include the dates of known fish kills. In 1986 no fish kills are known to have occurred.

For the 1984 simulation period, when natural flows averaged over 280 cfs (8 cms), the model predicted that the temperature threshold of 24°C would not have been exceeded (Table 6), if no diversion had occurred. The recorded flow at Aldersyde over that period averaged 174 cfs (4.9 cms) and water temperatures of 24°C were measured. In the 1985 simulation period, the model predicted that under natural flow conditions averaging 300 cfs (8.7 cms), water temperatures would exceed 24°C over 4 per cent of the time at sites both upstream and downstream of the Sheep River confluence. Actual flows over this period averaged 164 cfs (4.7 cms). The entire 1986 simulation interval showed no temperatures above 24°C under natural flow conditions (averaging over 350 cfs (10 cms)) or under actual flow conditions (averaging 239 cfs (6.8 cms)).

Further analysis focussed on defining the minimum streamflow that would have been required to maintain water temperatures below 24°C during the extremely hot weather conditions experienced in early July 1985. Air temperatures over the July 1 to 11, 1985 period ranged from 28.5°C to 33°C, averaging 31.4°C. Using these air temperatures and the associated meteorological data, the model was used to

TABLE 6

Summary Statistics on WQRRS Temperature Runs for the Highwood River.

ALL Changes are Relative to Simulated Natural Flows.

RUN		AVERAGE CHANGE IN DAILY MAXIMUM TEMPERATURE (°C)	PER CENT OF TIME TEMPERATURE > 24°C
1984 NATURAL	D/S HIGH RIVER		0.00
	U/S SHEEP		0.00
	D/S SHEEP		0.00
1985 NATURAL	D/S HIGH RIVER		0.00
	U/S SHEEP		4.30
	D/S SHEEP		4.20
1986 NATURAL	D/S HIGH RIVER		0.00
	U/S SHEEP		0.00
	D/S SHEEP		0.00
1985	D/S HIGH RIVER	0.58	0.00
CONSTANT FLOW -	U/S SHEEP	0.61	8.25
(6 cms) 212 cfs	D/S SHEEP	-0.43	0.00
1985	D/S HIGH RIVER	0.32	0.00
CONSTANT FLOW -	U/S SHEEP	0.29	6.19
(7 cms) 247 cfs	D/S SHEEP	-0.52	0.00
1985	D/S HIGH RIVER	0.09	0.00
CONSTANT FLOW -	U/S SHEEP	0.01	4.12
(8 cms) 282 cfs	D/S SHEEP	-0.62	0.00
1985	D/S HIGH RIVER	-0.08	0.00
CONSTANT FLOW -	U/S SHEEP	-0.22	1.03
(9 cms) 318 cfs	D/S SHEEP	-0.70	0.00
1985	D/S HIGH RIVER	-0.23	0.00
CONSTANT FLOW -	U/S SHEEP	-0.46	0.00
(10 cms) 353 cfs	U/S SHEEP	-0.78	0.00

simulate a range of constant flows varying from 212 cfs (6 cms) to 350 cfs (10 cms). An examination of the change in water temperatures indicated that for all flows above 212 cfs (6 cms), the 24°C threshold was not exceeded downstream of the Sheep River (Table 6). In the zone upstream of the Sheep River confluence, the frequency with which 24°C was exceeded was reduced from 8.25 percent at 212 cfs (6 cms) to 1.0 percent at 318 cfs (9 cms). At 282 cfs (8 cms), the frequency of exceedance was 4.12 percent, approximately equal to that under the natural flow conditions in 1985 (Table 6).

The model predicted that a constant flow of near 350 cfs (10 cms) would be necessary to keep water temperatures below 24°C during extended hot weather conditions such as occurred in early July, 1985. An examination of hydrological records shows that flows are naturally less than 350 cfs (10 cms) approximately 25 per cent of the time during the six-week period from July 1 to August 14. Thus, if 350 cfs (10 cms) was set as a temperature protection flow, it would not be met under natural conditions one summer in four. Since a flow of 282 cfs (8 cms) approximates the natural level of temperature protection in 1985, and since it is achievable 85 per cent of the time, it is considered to be a reasonable temperature protection flow. The model

predicted that a flow of 282 cfs (8 cms) would have prevented the occurrence of temperatures of 24°C in 1984, when there were several occurrences of high temperature events of five-day duration.

To evaluate the natural risk associated with a flow of 282 cfs (8 cms), hydrological records and air temperature records were examined. The probability of flows less than 282 cfs (8 cms) between July 1 and August 14 is 14.6 per cent. The probability of air temperatures above 30°C, or greater than 27°C for three successive days, is 10 per cent. The probability of experiencing these flow and weather conditions together is the product of the two probabilities (0.146 x 0.10), approximately 1.5 per cent. Under natural conditions, then, the combination of low flow and high air temperatures that result in water temperatures hazardous to fish in the lower Highwood are expected to occur 1.5 per cent of the time in the six-week period from the beginning of July to mid-August.

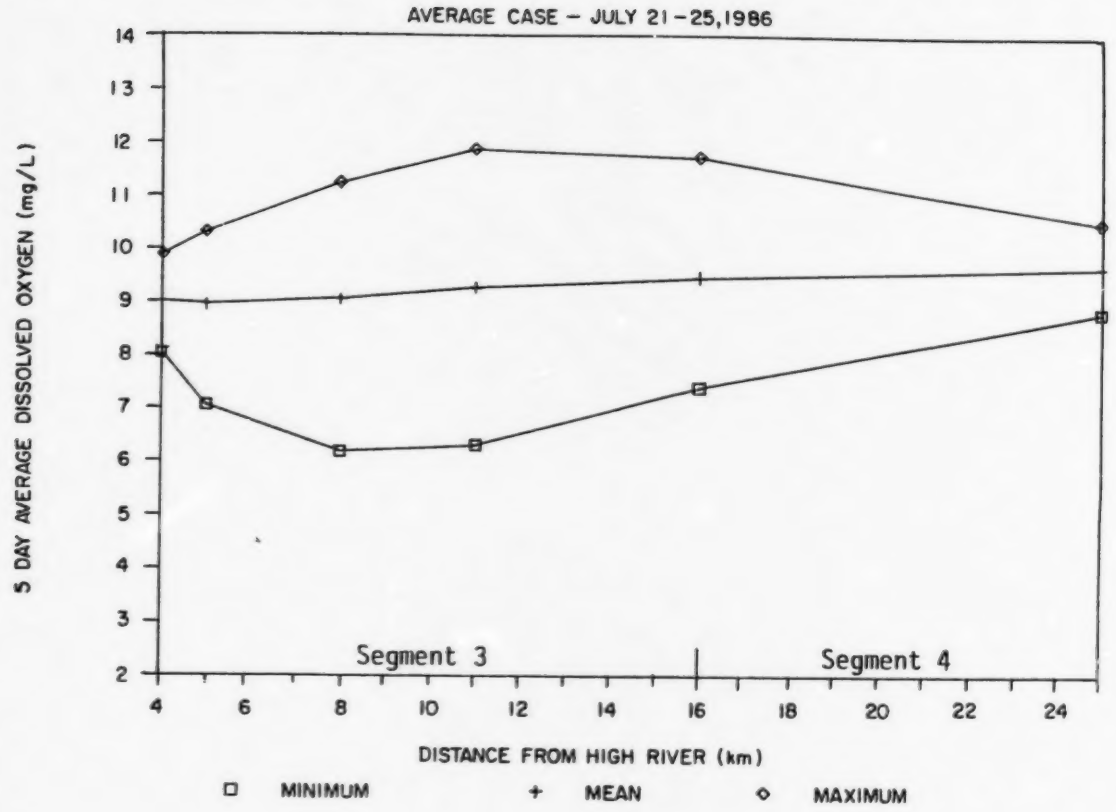
3.2.4.2 Oxygen

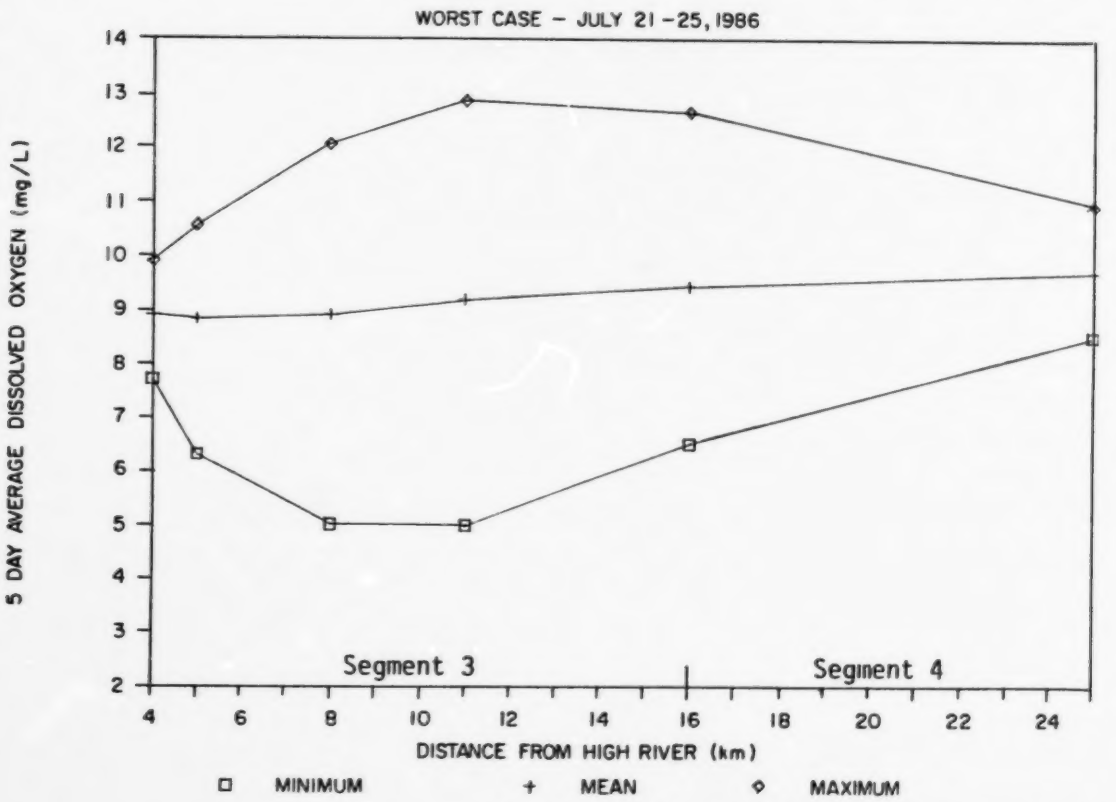
Initial field studies and preliminary oxygen modelling indicated that the critical reach of the Highwood River for nighttime minimum oxygen is a 7 km stretch of river located between 4 and 11 km downstream of High River. Extensive weed beds are present in this wide, low-gradient stretch of

river. The nighttime removal of oxygen by aquatic plants, combined with low streamflows, results in minimum oxygen levels in the pre-dawn period.

This stretch of river corresponds to a portion of Segment 3 (Figure 1), which is upstream of the segment for which physical habitat flows were developed (Segment 4). While little suitable salmonid habitat is found in Segment 3, it comprises an important zone of passage. Modelling for this reach focussed on determining the minimum flow required to sustain oxygen levels above 4 mg/L even under high temperature regimes. The longitudinal pattern in river oxygen (Figure 7) shows that minimum oxygen values increase downstream, such that a level of 5 mg/L or greater would be attained in Segment 4 under the worst case scenario. The Alberta Surface Water Quality Objective for oxygen in surface waters is 5 mg/L.

The diurnal oxygen pattern was simulated at flows ranging from 70 cfs (2 cms) to 282 cfs (8 cms) for three intervals - July 21 to 25, 1986; August 4 to 9, 1986 and July 27 to August 3, 1984. The 1984 simulation interval covered a known period of fish mortality, with dissolved oxygen levels in the range of 2 to 3 mg/L measured prior to dawn. The model was run under an average-case and a worst-case situation with respect to respiration rate, photosynthesis rate and aquatic plant biomass. For the





LONGITUDINAL OXYGEN PATTERN FOR THE HIGHWOOD RIVER DOWNSTREAM OF HIGH RIVER

FIGURE 7

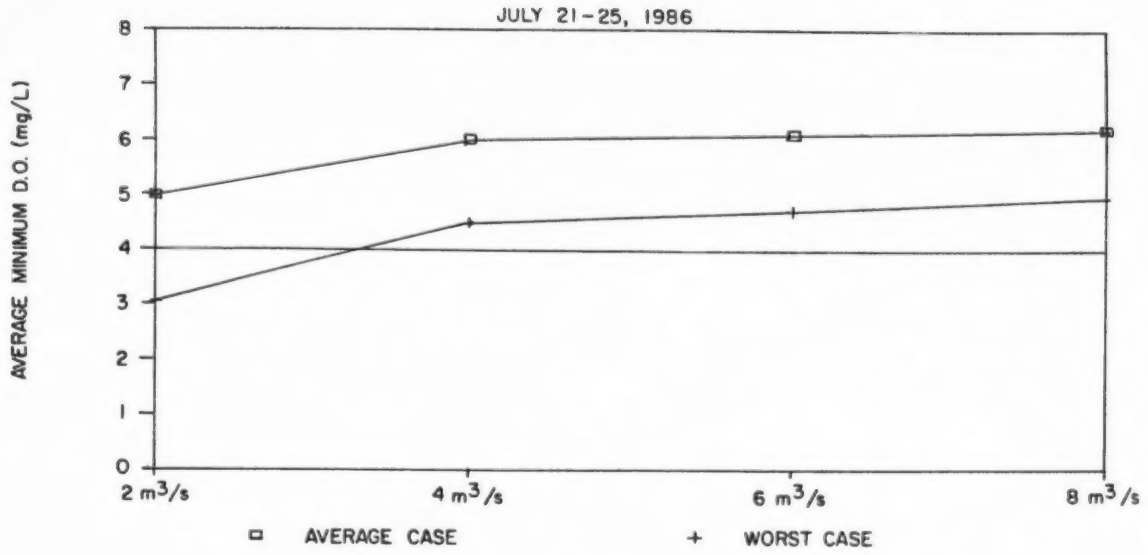
worst-case situation, each of the three parameters were increased by 25 per cent. This range of conditions was chosen to allow for biological variability within one season and between years.

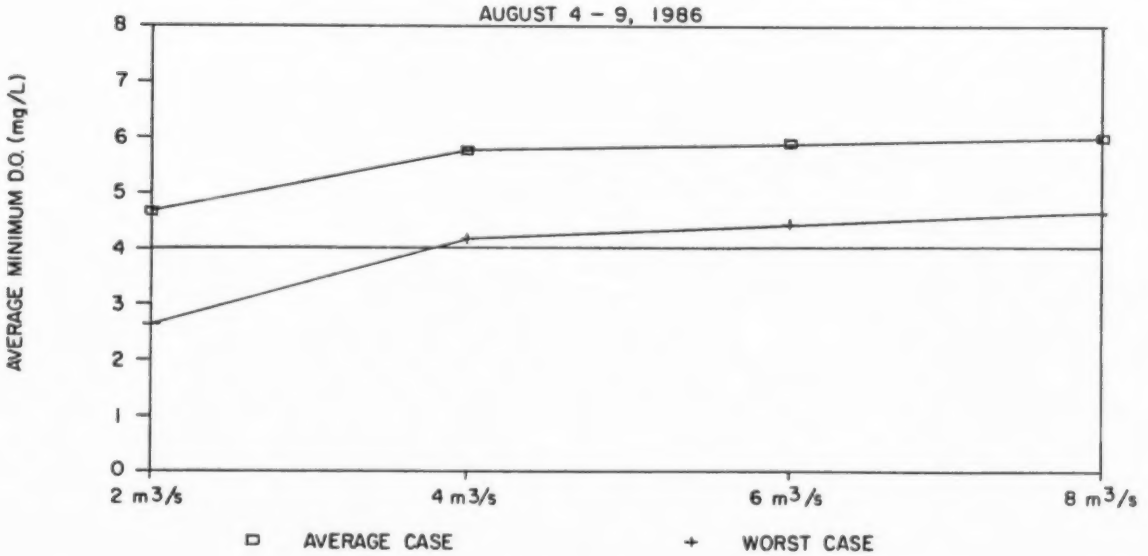
For all three simulation intervals, the 4 mg/L objective was not met most of the time under the average-case and worst-case situation at a flow of 70 cfs (2 cms). When the flow was increased to 140 cfs (4 cms) the average case violations were eliminated, but violations under the worst-case scenario of enhanced photosynthesis, respiration and aquatic plant biomass were maintained. At 212 cfs (6 cms), the worst-case violations of 4 mg/L were generally eliminated for the 1986 simulation intervals and the 1984 situation was improved. Increasing the flow to 282 cfs (8 cms) did not improve oxygen levels significantly.

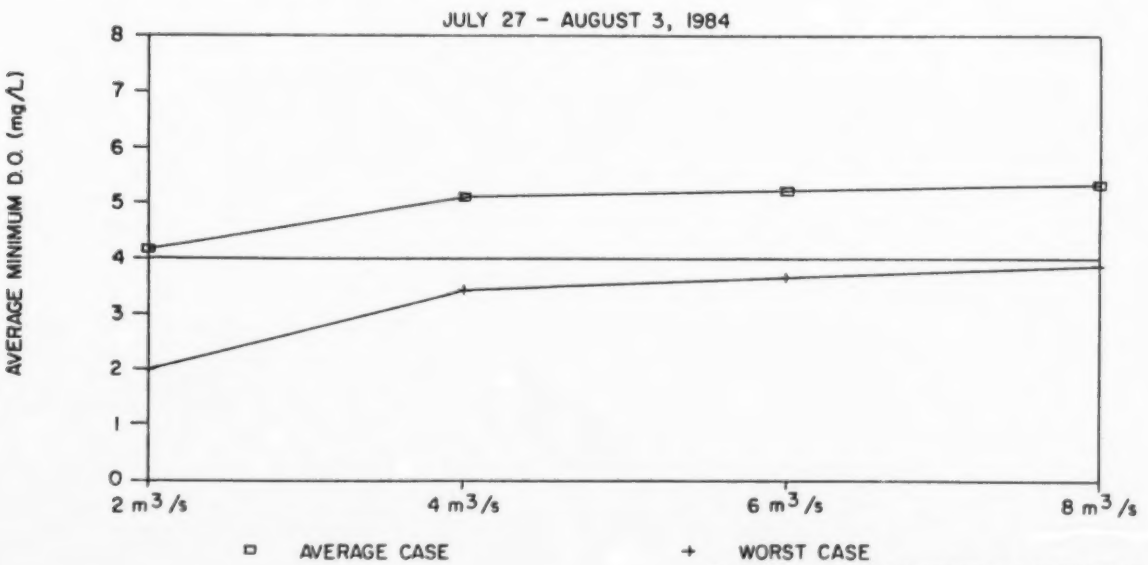
The relative change in oxygen levels with increasing flow was not linear (Figure 8). Maximum rate of improvement occured as flows increased from 70 cfs (2 cms) to 140 cfs (4 cms), and the improvement rate beyond that was less.

This analysis indicates that nighttime oxygen levels in the zone of worst weed growth can be maintained at or near 4 mg/L under high temperature conditions when river flows are maintained at 212 cfs (6 cms).

Hydrological records were examined to evaluate the natural risk associated with an oxygen protection flow of







CHANGE IN AVERAGE MINIMUM OXYGEN WITH INCREASING FLOW

FIGURE 8

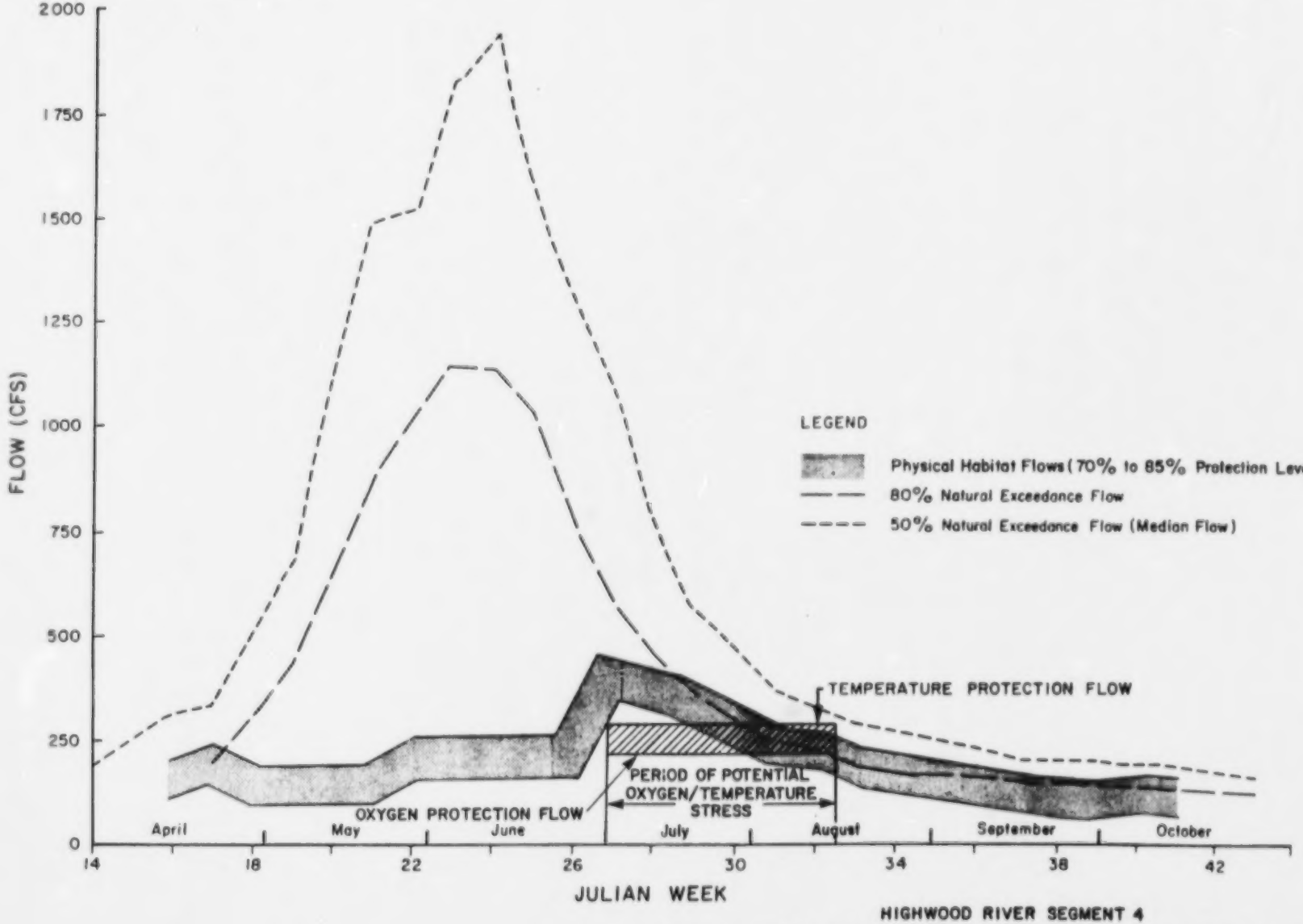
212 cfs (6 cms). Over the six-week period from July 1 to August 15, flows greater than 212 cfs (6 cms) can be expected 95.2 per cent of the time. Conversly, flows which may result in hazardous oxygen conditions can be expected in the lower Highwood River 4.8 per cent of the time under the natural flow regime. These events, however, only result in fish kills when they occur coincidently with hot weather conditions.

4.0 DISCUSSION

4.1 ATTAINMENT OF PROTECTION FLOWS

The protection flows developed in this study cannot be achieved every week of every year except during the May and June peak runoff period. Under natural conditions over the April 16 to October 14 period, the flows sufficient to meet the four levels of physical habitat protection (70, 75, 80, 85 percent) are exceeded a minimum of 89, 82, 74 and 68 percent of the time, respectively. On average they are exceeded 97, 95, 90 and 85 percent of the time. The oxygen protection flow is exceeded over 95 percent of the time from July 1 to August 15, and the temperature protection flow is exceeded 85 percent of the time over the same summer period.

Figure 9 shows the physical habitat flow range, the temperature protection flow and the oxygen protection flow compared to the flows that are exceeded 50 percent and 80 percent of the time in Segment 4. During May and June, the flows required for physical habitat protection are well below those that occur naturally. Since natural flows during the peak spring runoff period (May and June) are greater than the corresponding calculated optimum flows for physical habitat protection in Segment 4, it may be beneficial to fish if the flows were reduced during this period. It should be noted, however, that flushing flow requirements have not been taken into account in this analysis. Natural flows during the important summer and early fall months are historically relatively close to computed physical habitat flows. This indicates that removal of a relatively small amount of water during this time of year could result in significant degradation of fish habitat.



HIGHWOOD RIVER SEGMENT 4

PHYSICAL HABITAT, 80% AND 50% NATURAL EXCEEDANCE AND TEMPERATURE AND OXYGEN PROTECTION FLOWS

FIGURE 9

All risks to aquatic life could not be eliminated if the flows derived in this study were instituted; however, the risk would be considerably reduced compared to the conditions that could occur under the present operating guidelines. If the aquatic resources of the lower Highwood River are to be afforded a reasonable degree of protection, it is particularly important that adequate flows be provided during periods of hot weather when risks to aquatic life are greatest.

If flows are sufficient to protect the sportfish habitat and to maintain suitable water quality conditions, the aquatic ecosystem should remain healthy. Salmonids are relatively sensitive to environmental conditions, therefore if physical and water quality conditions are suitable for their survival, the other components of the aquatic community should be protected.

4.2 FURTHER CONSIDERATIONS REGARDING ANALYSIS

The magnitude of the derived flows for physical habitat and water quality protection was affected by a number of factors and subjective decisions. An awareness of these factors and decisions is important in understanding the results of the analysis.

A major factor influencing the determination of physical habitat flows was the selection of the degree of habitat protection. In this study, flows which would protect 70, 75, 80 and 85 percent of the habitat occurring at median historical natural flows or at optimum flows, whichever was less, were selected. The selection of these levels of habitat protection was somewhat subjective; however, similar levels have been used in previous studies on other salmonid streams. Given the importance of the Highwood River in providing salmonid habitat, a level

of protection in this range was considered to be warranted, however, it is subject to further discussion and ratification.

Another factor influencing the magnitude of physical habitat flows was the nature of the fisheries management objectives for the lower Highwood River. Fish and Wildlife Division's management objectives called for the provision of flows to protect rainbow trout and mountain whitefish populations, with rainbow trout weighted over mountain whitefish by a factor of three to one. This weighting reflects the greater importance placed on the Highwood River as a spawning and rearing stream for the Bow River trout fishery; it is not a reflection of the number of rainbow trout compared to mountain whitefish. A subsequent evaluation was undertaken at the request of Fish and Wildlife Division using a one to one ratio of these two species, i.e., equal weighting, in order to determine how the flows would change from those derived using a three to one weighting. Since mountain whitefish require higher velocities and the attendant higher flows, the physical habitat flows derived by using a 1:1 ratio were higher at all times. The increase in flow volumes ranged from 6 per cent to 68 per cent, and the natural flow exceedance of these higher flows ranged from 63 per cent to 100 per cent. Except in May and June, the attainment of these flows under natural conditions would be reduced if rainbow trout and mountain whitefish were weighted equally.

The analysis undertaken to derive a temperature protection flow was based on not exceeding 24°C, a water temperature considered hazardous for sportfish. Possible sub-lethal effects of high water temperatures over prolonged periods were not evaluated. For oxygen protection, flows were

derived that would support at least a level of 4 mg/L of dissolved oxygen for Segment 3 and at least 5 mg/L in Segment 4. As was the case for temperature, the effects on fish subjected to dissolved oxygen levels near these minima, and the level at which they could succumb to oxygen stress are unknown. Sub-lethal effects of high temperatures and low oxygen on fish are ill-defined, and the possible synergistic effect of the two conditions occurring together are unknown. Since detailed water quality standards for sub-lethal effects of temperature and dissolved oxygen are not available, further analysis is precluded at this time.

Another factor pertaining to the analysis of temperature is the evaluation of risk. While the probability of hot weather conditions (i.e., greater than $30^{o}C$) occurring over the July 1 to August 15 period was determined to be 10 per cent, it should be noted that this 10 per cent of days were not evenly distributed over the years. Many years over the 55-year period of meteorological record had no instances of 30°C days, whereas dry, hot years like 1936 and 1985 had 14 and 9 days respectively over 30°C. In each year from 1983 to 1985, hot weather conditions were experienced in combination with the low flows, and in each of these years, fish kills resulted. On average, however, in 27 percent of years, or approximately one year in four, weather conditions occur that, in combination with low flows, could cause lethal water temperatures.

An examination of recorded flows in the July 1 to August 15 period from 1977 through 1985 revealed that they were less than the temperature protection flow of 282 cfs (8 cms) in 50 percent of the weeks. Considering the 10 percent probability of air temperatures exceeding

$30^{o}C$ indicates that, during this period, the lower Highwood River was at a water temperature risk 5 percent of the time. Fish kills were experienced in 5 of these 9 years. Modelling of temperature and flows predicted four of these five events, yielding good agreement between the predicted and historic events.

A further consideration regarding the oxygen analysis is that the flow derived for oxygen protection is based on present conditions of weed growth, and the present effluent loading from the High River sewage treatment plant. The zone of heaviest weed growth presently extends throughout Segment 3, approximately from downstream of the High River sewage treatment plant to Highway 2 crossing. This stretch of river provides near-ideal physical conditions for weed growth due to its low gradient, low velocities and fine substrates. The nutrient enrichment from the sewage further enhances aquatic plant growth. At the present minimum flow of 70 cfs (2 cms) the dilution of effluent is approximately 70:1. This degree of dilution in the summer months has led to complaints from residents along the lower river.

By late 1987, a new sewage treatment plant for the Town of High River will be in place. It will be situated several miles downstream of the town, near the confluence of Tongue Creek (Figure 1). This location is near the downstream end of the most dense weed beds. The implications of moving the effluent outfall to a new location are not clear; it is uncertain whether any improvement in weed densities will result. The nutrients stored in sediments and input from agricultural and other non-point sources may continue to support heavy weed growth under the near-ideal physical conditions present between the town and the new sewage treatment plant.

The quality of the effluent from the new sewage treatment plant will be better than that from the present plant, with phosphorus levels likely to be reduced by 10 to 25 per cent. The volume of effluent released will be similar to the present volume (1 cfs). The new plant will have the capacity to store effluent for up to 15 days. This storage capacity could be of benefit if some malfunction were to occur, as the effluent could be held back until problems are resolved. There is no storage capacity at present, and any malfunction, such as the one which occurred in late July, 1984, can have immediate negative effects on the river. Future monitoring in the lower Highwood River is warranted to document any impacts which may result from the change in sewage treatment plant location and effluent quality.

4.3 APPLICATION OF PROTECTION FLOWS

The physical habitat flows and water quality protection flows developed in this study are designed to provide adequate fish habitat over the open water period, to maintain suitable temperature and oxygen conditions over the critical summer period, to provide improved dilution of sewage effluent and in general, to ensure that the lower Highwood River remains a productive ecosystem. It should be emphasized that these are minimum flows and should not be interpreted as target flows for water management. To maintain the ecological diversity that has made the Highwood River such valuable habitat it is necessary to retain a certain variability in flows. Continuous and/or repeated reduction of river flows to minimum levels would result in a gradual deterioration in the general health of the Highwood River ecosystem.

Water balance studies have revealed that at the diversion canal sizes being considered in the Little Bow Basin planning studies, diversions from the Highwood could not significantly affect flow variability in the spring and early summer. In fact, flow reduction in this period is expected to improve habitat over natural conditions. However, during late July, August and September, it is possible to regularly reduce Highwood River flows to the general category of protection flows described in this report. Regular reduction of flows to these levels would be detrimental, since average flow conditions in the late July to September period are naturally limiting to fish habitat. Water quality conditions in the July-August period could also become critical to the sportfish. The reduction of sudden flow surges due to storms could be beneficial; however, the magnitude of such reductions would require further evaluation. Some mechanism must be built into the operating rules for the diversions to ensure that a degree of flow variability is maintained in the lower Highwood River.

The protection flow values developed in this study are preliminary. More detailed analysis is continuing and monitoring of habitat conditions in the Highwood River is ongoing and will accompany any water management development in the basin. As conditions in the river change and as a greater understanding is developed of the relationship between flows and fish habitat and water quality, it is expected that these flows will be adjusted. Also, the physical habitat flows did not take into consideration the need for spring flushing flows. This was not a concern under the diversion scenarios being examined as the effect on spring freshet flows was not significant. If water management developments that

could significantly alter spring flows were to be considered, flushing flow requirements would have to be addressed.

It should also be recognized that any future uses of Highwood River water have not been considered in this report, i.e., no allowances have been made to provide flows for future downstream withdrawals. Further water management planning in the Highwood River basin will have to take this into account.

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